DOCUMENT RESUME

ED 039 713 | 56 | EM 008 046

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TITLE	Computer Assisted Instruction in Elementary/Secondary Education: The State of the Art.
INSTITUTION	Academy for Educational Development, Inc., Washington, D.C.
SPONS AGENCY	Office of Education (DHEW), Washington, D.C. Bureau of Research.
BUREAU NO	BR-8-0571
PUB DATE	[70]
NOTE	37p.; This is one of the support papers for "To Improve Learning; a Report to the President and the Congress of the United States by the Commission on Instructional Technology", ED 034 905
EDRS PRICE	EDRS Price MF-$0.25 HC-$1.95
DESCRIPTORS	*Computer Assisted Instruction, *Educational Change, Elementary Education, Secondary Education
IDENTIFIERS	Drill and Practice

ABSTRACT

Computer assisted instruction (CAI) is defined in this paper as a process which exploits the memory capacity and computational capabilities of a computer to allow a unique interaction between a student and curricular subject matter. Several modes of CAI are briefly described; in a CAI overview, the drill and practice mode is focused on elementary and secondary education, with reference to the relationship between the improvement of public education and the attempt to confront socioeconomic crises. The need for the development of a more economical CAI system is also stressed. (SP)

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COMPUTER ASSISTED INSTRUCTION

IN ELEMENTARY/SECONDARY EDUCATION:

THE STATE OF THE ART

by Lawrence Parkus*

Introduction

Computer assisted instruction has been subject to a good deal of definitional confusion. For some, CAI capaciously describes any application of the computer in an educational institution. Others rigidly apply the term to include only that tiny fraction of computer applications marked by intensive and highly sophisticated student-computer communication. A realistic definition -- in terms of the state of the art now and in the near future -- lies somewhere between the generalized and particularized versions mentioned above. For the purposes of this report, CAI is defined as a process which exploits the memory capacity and computational capabilities of a digital computer to allow a unique interaction between a student and curricular subject matter. Typically, this involves a terminal, which allows a student to receive and transmit information, linked to a computer which stores and regulates the flow of information to and from the student. There are several distinguishable forms, or modes, of CAI: these are briefly described below. The development and growth of CAI -- in all its configurations -- is, above all, a function of its rich potential to support the individualization of instruction.

The depth, intensity, and flexibility of student-computer interaction define both the CAI mode and the nature of the equipment (hardware) and

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curricular programs (software) required. The simplest mode of CAI, i. e., the lowest interactive level, is Drill and Practice. In this application, the presentation of concepts, indeed, of all new information, remains the sole responsibility of the teacher. Here, the role of CAI is to evaluate a given student's understanding of the material which has been presented and then to present a program of drill and practice which is most applicable to his particular needs. The overall function of the drill and practice mode is to provide maintenance of skills and retention of concepts. Because this is the dominant application of CAI in elementary/secondary education, it will be further explored below.

In the tutorial mode of CAI, the computer system introduces concepts and new information in varying degrees as well as provides maintenance of skills and retention of concepts. Although, as will be seen below, both drill and practice and tutorial systems provide branching to varying levels of difficulty, the student, in both systems, is quite restricted in his ability to really manipulate the subject matter being studied. The student is limited to constructed responses: he is rigidly limited in the case of drill and practice (e. g., "yes", "2 + 2 = 4"), less limited in some tutorial applications (e. g., "The Chief Executive Officer of the U. S. is the President" or "The President of the United States").

Problem-Solving is a CAI mode which permits a greater degree of flexibility in the interaction of student and subject matter. By the use of a computer language, the student may exploit the enormous calculating capability of a modern computer in manipulating large and complex data bases necessary to the solution of problems in science and engineering. Systems Development Corporation, for example, has developed a college-level statistics course -- implemented at UCLA -- which allows a measure of realism in student handling of complex data unavailable in traditional teaching situations. The necessity for student knowledge of a computer language and the general paucity of software has severely restricted the application of problem-solving CAI in the public schools.

Simulation and Gaming applications of CAI too allow for a more rigorous and flexible student-curriculum materials interaction. Typical of experimentation in this area is the development of economic games by the Board of Cooperative Educational Services (BOCES) of Westchester County, New York. At the BOCES Center in Yorktown Heights, a CAI system simulates diverse economic environments -- as diverse as the ancient kingdom of Sumer and the contemporary nation of Sierra Leone -- and sixth grade students on terminals are provided the opportunity to make critical decisions effecting these simulated economic systems. While the Yorktown Heights experiment has demonstrated real promise,

very few similar applications are to be found in the public schools -- again, the funding and the expertise necessary for the development of simulation programs have not been available.

A Dialogue mode would be an ultimate in CAI development. Such a system would permit a student to input free-form questions and statements and, in so doing, would create a totally flexible interaction, a curricular dialogue, between pupil and computer. Elements of existing CAI programs approach this ideal. A logic program developed by Patrick Suppes at Stanford, for example, will accept any line in a proof or derivation if such a student response does not violate the rules of logic. Generally, however, free interaction in CAI is very much in the research stage and no existing CAI system can be accurately categorized a dialogue system.

This report will concentrate upon the application of drill and practice CAI in elementary/secondary education. In focusing upon the public schools, this report falls within an emerging consensus -- recently stated in forceful terms by the new national administration -- which recognizes the critical relationship between the improvement of public elementary/secondary education and the attempt to confront the socioeconomic crises which plague us. Drill and practice CAI receives special attention in this

report because, within the public school environment, it is the state of the art. State of the art is defined here quite simply as that which is possible -- and has been proven so by extensive, relatively efficient applications. Another way of saying this is that selective emphasis is placed upon operational CAI -- installations where a meaningful number of students receive a significant portion of their instruction in at least one subject area under computer control -- rather than CAI locations which are of a research or demonstration nature.

CAI in the Schools: An Overview

The introduction of CAI in elementary/secondary education has been a slow process. As early as 1961, Professor D. L. Bitzer of the Coordinated Science Laboratory of the University of Illinois was employing a one terminal CAI system, PLATO I, to provide instruction in a variety of curriculum areas. Some eight years later, however, there are fewer than one thousand CAI terminals in the public schools serving fewer than twenty thousand students. When we subtract from these totals terminals and students involved in limited experimental and demonstration projects, we find that the parameters of operational CAI shrink to less than five hundred terminals and sixteen thousand students. This situation is summarized in Figure 1.

Figure 1: Operational CAI Installations, January 1969

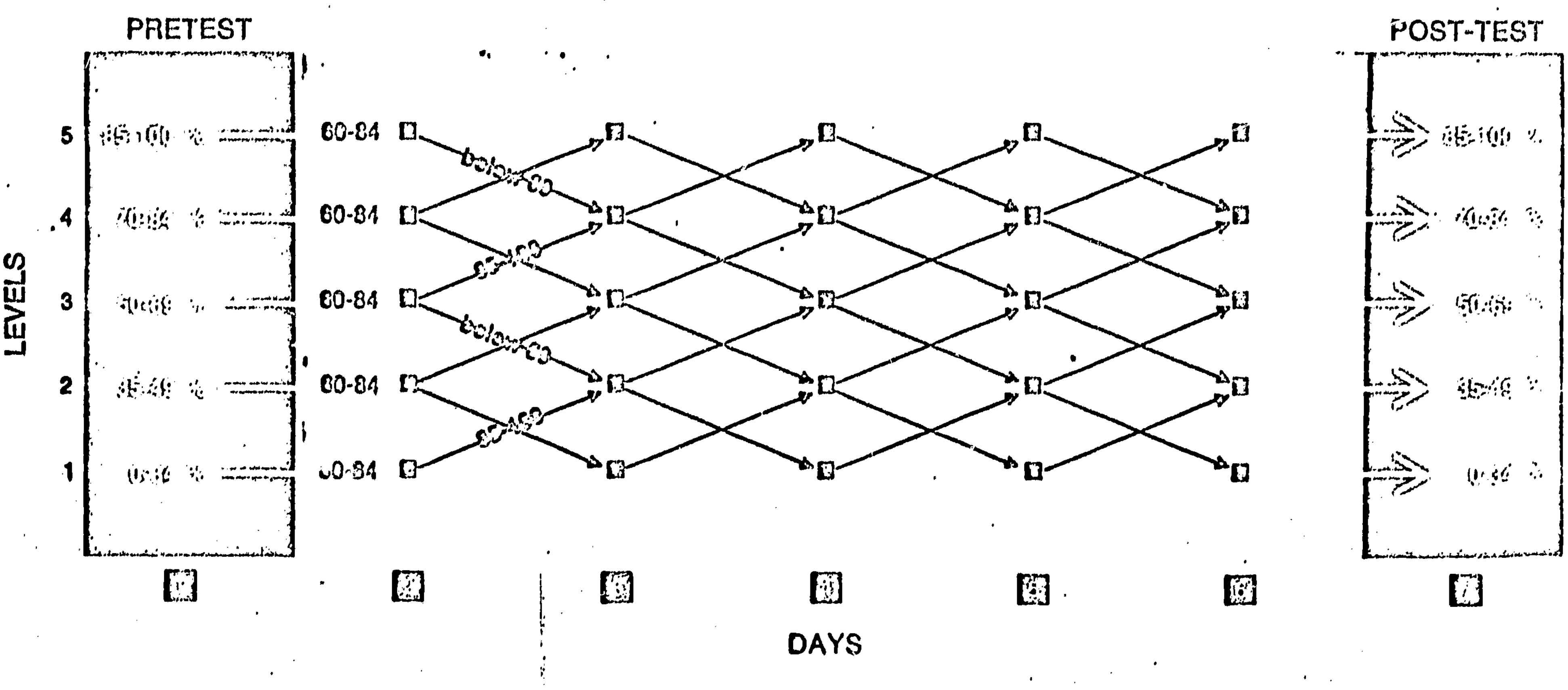
Installation	Number of Terminals	Number of Students	CAI Subjects	Grade Level(s)	CAI Mode(s)
New York City (Board of Education)	192	6,000	Mathematics	2 - 6	Drill & Practice
Philadelphia -- Project GROW	32	464	Biology, Reading	Junior High School Senior High School	Drill & Practice/ Tutorial
Eastern Kentucky Consortium	32	1,920	Mathematics	2 - 6	Drill & Practice
McComb, Mississippi	60	2,500	Mathematics	2 - 6	Drill & Practice
Waterford, Michigan INDICOM Project	32	400	Mathematics	2 - 6	Drill & Practice
San Francisco Bay Area Schools (Stanford Computer)	122	4,880	Mathematics, Reading, Computer Programming, Logic	2 - 12	Drill & Practice/ Tutorial (52 terminals used for mathematics drill and practice)
Commonwealth Consortium: Pittsburgh, Philadelphia, Pennsylvania State University -- to be operative in September 1970.	64	512	General Mathematics Algebra	9	Tutorial
TOTAL	534	16,676			

Figure 1 clearly shows that mathematics drill and practice at the elementary school level accounts for a large percentage of what has been defined as operational CAI. All of these mathematics drill and practice programs have a common derivation: the materials were originally developed at The Institute for Mathematical Studies in the Social Sciences at Stanford University under the leadership of Dr. Patrick Suppes and Mr. Max Jerman. The original Suppes-Jerman program is used by the CAI installations in Eastern Kentucky; McComb, Mississippi and the San Francisco Bay Area. The L. W. Singer Company has published the Suppes-Jerman program in computerized form and this version is utilized by the New York City CAI project. Given the relative pervasiveness of the math drill and practice program, a description of its operation is necessary to an understanding of CAI in the schools.

The math drill and practice program is structured as follows: The content of the mathematics curriculum for the entire year is divided into twenty-four concept blocks -- at each grade level. Each block is comprised of seven drill lessons. Each lesson exists in five versions representing five levels of difficulty. The first drill lesson in each concept block is a pretest: the student's score on the pretest determines the difficulty level (1-5) of the lesson drill which will be presented to him on the following day. The levels of difficulty for subsequent drills are

similarly determined by the performance of the individual student. If the student's score falls in the range of 60-84% correct, he remains at the same level of difficulty on the following day. If, however, the student scores 85% or better on a drill lesson, he is automatically raised one level of difficulty on the following day; if he scores below 60%, he is lowered one level. This branching structure is depicted in Figure 2.

Figure 2: Branching Structure for Regular Drill on a Concept Block



CAI drill and practice also provides for a system of individualized review lessons. A computerized record is kept of a student's performance on block post-tests (see Figure 2), and, on the basis of those performances, review lessons at the appropriate level of difficulty are prescribed. There is an extensive attempt to individualize the reviews: four separate sets of reviews of each concept block have been written and each review has been constructed at five levels of difficulty. Further, a series of review tests are designed to measure the effectiveness of the review lessons and provide the basis for continuing diagnosis. Generally, these procedures appear to ensure that a student, throughout the year, is reviewing his weakest areas.

A daily drill varies in duration from four to ten minutes. Problems are presented in a variety of formats thus encouraging the student to broadly apply his understanding of concepts and to recognize those concepts in various guises. A teletypewriter serves as the instructional terminal: problems are displayed in hard copy print-out form and student responses are effected via the keyboard. Typically, student responses are instantaneously reinforced. If the student's response is incorrect, "No, try again" is typed out and the problem is displayed again. If a second error is made, the correct answer is displayed and the student is instructed to "Try again". The problem is once again displayed and the student is permitted to insert the correct answer. The daily lesson which is re-

produced in Figure 3 consists of drill on a new concept block followed by a review of an earlier concept block on which the student had performed poorly. The drill is Grade 4, Concept Block 19, third level of difficulty and is a mixed drill treating arithmetical functions as well as the commutative, associative and distributive laws.

Figure 3: Sample Mathematics Drill 2
Practice Lesson

```
PLEASE TYPE YOUR NUMBER.  164
NOW YOUR FIRST NAME.  JOHN SMITH
THIS IS A MIXED LESSON.
27 x (13 + 15) = (27 x 13) + (27 x 15)
8 x 70 = 570
NO, TRY AGAIN.
8 x 70 = 560
IF JEFF ATE 1 5 OF THE 450 COOKIES AT THE PARTY,
HOW MANY COOKIES WERE LEFT FOR THE OTHERS?
90 COOKIES
9 x 30 = 270
IF MARY PUT 30 DONUTS IN EACH OF 9 BOXES, HOW MANY
DONUTS WERE THERE ALL TOGETHER?
___DONUTS
TIME IS UP. TRY AGAIN.
___DONUTS
TIME IS UP.  THE ANSWER IS 270.  TRY AGAIN.
270 DONUTS
6/3 6 3     60
  3 6 0
      3
80 x 9 = 720
17/29 - 9/29 = 6 29
NO, TRY AGAIN.
17/29 - 9/29 = 9/29
NO, THE ANSWER IS 8.  TRY AGAIN.
```

17/29 − 9/29 = 8/29

57 − 47 = 47 − 37 .

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9/2 7 9    30
  2 7 0     1
      9

 3 0
+  1
 3 1
```

24 x (16 + 19) = (4 x 16) + (24 x 19)

TIME IS UP. TRY AGAIN.

24 x (16 + 19) = (14 x 16) + (24 x 19)

NO. THE ANSWER IS 24. TRY AGAIN.

24 x (16 + 19) = (24 x 16) + (24 x 19)

IF THERE ARE 48 CHILDREN IN THE CLASS AND 1/4 OF THEM ARE GIRLS, HOW MANY BOYS ARE IN THE CLASS?

36 BOYS

4 x 60 = 240

(27 + 70) + 83 = 27 + (27 + 83)

NO. TRY AGAIN.

(27 + 70) + 83 = 27 + (70 + 83)

END OF LESSON NUMBER 11431902

15 PROBLEMS CORRECT. 75 PERCENT. IN 242 SECONDS

72 PERCENT CORRECT FOR ALL LESSONS THIS YEAR

THIS IS A REVIEW ON UNITS OF MEASURE.

1 2 YEAR = 6 MONTHS

3 NICKELS = 15 CENTS

2 PINTS = 5 CUPS

NO. TRY AGAIN.

2 PINTS = 3 CUPS

NO. THE ANSWER IS 4. TRY AGAIN.

2 PINTS = 4 CUPS

1 2 DAY = 12 HOURS

1 YEAR = 365 DAYS

1 2 FOOT = 8 INCHES

NO. TRY AGAIN.

1 2 FOOT = 6 INCHES

END OF REVIEW NUMBER 12411701 OCT. 6, 1967

4 PROBLEMS CORRECT. 67 PERCENT. IN 69 SECONDS

GOOD-BY, JOHN. PLEASE TEAR OFF AT THE DOTTED LINE.

... ...

The results that have been achieved with CAI math drill and practice will be summarized in the section that follows. Before turning to this subject, however, a few comments on several of the installations summarized in Figure 1 are offered because of their relevance.

There are plans within the New York City project to employ their computer in administrative data processing applications during time periods when the CAI system is not in operation. Computerized test scoring, for example, is one area receiving serious consideration: well over five million tests per year would be compatible with computer-scoring. A pattern of utilization which combined CAI with ADP applications could significantly reduce the high per-student CAI costs which are detailed in the costs section of this report.

Twenty-eight elementary schools in seven counties participate in the Eastern Kentucky CAI project. Created by an ESEA Title III grant, this project offers a unique opportunity to gauge the effectiveness of CAI with children living in an economically depressed rural area -- the seven counties fall squarely within Appalachia. In addition to elementary school children, many of whom fall far below their formal grade levels in mathematics achievement, the system will be used by Neighborhood Youth Corps trainees, by Upward Bound enrollees, by adults taking basic

education courses and by special education students. There is a good reason to believe that the Eastern Kentucky project will, over time, provide a basis for evaluating the effectiveness of CAI in remedial education.

The Commonwealth Consortium project (Philadelphia, Pittsburgh, Pennsylvania State University) promises to offer the most extensive test to date of tutorial CAI in the public school environment. Commencing in September, 1970, five hundred twelve ninth-grade pupils will spend a total of 2,560 hours per week on computer terminals in the study of general mathematics and algebra. These will truly be "stand-alone" CAI courses -- teachers will not be assigned to the experimental groups. The development of the CAI programs in the CAI Laboratory at Pennsylvania State University and the results achieved in the classrooms of Philadelphia and Pittsburgh should provide the kinds of data necessary for a cost-effectiveness analysis of tutorial CAI.

CAI in the Schools: Acceptance and Results

There has been relatively little CAI in the schools; there has been practically no systematic assessment and evaluation of the effects of the medium where it has been employed. In some cases, CAI installations have not had access, either internally or externally, to personnel qualified

to conduct valid evaluations; in other instances, the individuals responsible for CAI have been preoccupied with the myriad problems accompanying the introduction of a highly innovative program and, therefore, have postponed evaluation. It would be unrealistic to assume that this situation will change, that, in some way, systematic evaluation will automatically be built-in to future CAI projects. Accordingly, there is an urgent need to deeply involve specialists in learning research from the university community in the systematic assessment and evaluation of present and future CAI applications in the public schools. Federal and state educational funding authorities must assign a higher priority to this need than they have in the past.

The relatively few studies which have been conducted on CAI effectiveness do create a basis for optimism about the eventual contributions of the medium. These studies, as well as the reactions of those who have experienced the application of CAI in the schools are summarized below.

Eastern Kentucky. According to Dr. Leonard Burkett, Program Coordinator and Professor of Education, Morehead State University, the introduction of CAI has resulted in widespread educational benefits. Students, on the whole, are strongly motivated by the medium: this new enthusiasm and motivation to learn was reflected in marked improvement

in student attendance at schools where terminals were installed. A number of observers reported that experience on the terminals appeared to have increased the confidence of particularly disadvantaged students with long histories of failure. The judgments of the computer, impersonal and private, appear to cause such students much less embarrassment and frustration than did their previous experiences with classroom teachers. This observation, when coupled with a number of other factors, strongly suggest that CAI may have the ability to reach those students who are unresponsive to traditional instruction. Of similar interest is the observation that a significant number of students with CAI experience made marked gains in reading and language arts skills, although the CAI curriculum was exclusively in the area of mathematics. This "spin-off", which has been observed in several other CAI projects, appears to result from the general motivation to learn engendered by the medium as well as the systematic, relatively fast manner in which the instructional material is presented and the ability of this procedure to increase student concentration.

On balance, CAI has had a positive effect upon the performance of classroom teachers. The logical and sequential nature of the CAI programs has made a significant contribution to the planning and execution skills of

a number of teachers involved in the project: as a result of their experiences, they are better prepared, on a daily basis, to specify their instructional objectives and to systematically plan the sequence of activities which will achieve those objectives. Also, the program has resulted in significant economies of time for the classroom teacher by eliminating the routine of classroom drill and the burden of preparing, correcting and recording large numbers of drill and practice exercises. More than ever before, this has freed teachers to work with students in individual and small group situations. In these individualized or small group situations, the CAI system has proven a powerful diagnostic tool: by typing in a simple code on the teletype terminal, the teacher can receive a summary of the work of a class, the class's work on a given concept, or the work of an individual pupil. The teacher has been in a position, therefore, to go beyond even the individualized CAI review routines in attacking specific areas of individual weakness.

The Kentucky project has been positively received by parents. The printouts of students' daily drill lessons are taken home and this, according to Dr. Burkett and others, has resulted in much greater parental interest and involvement than had been the case in the project schools before CAI. Special observation and demonstration programs for parents have been extremely well attended.

Nothing approaching a comprehensive evaluation has been conducted in Eastern Kentucky; however, the limited measures taken of the effectiveness of CAI are suggestive of promising potential. One study involved the seventh grade class at the Morehead State University Laboratory School. The Stanford Achievement Test was administered to the twenty-six class members. The class mean for arithmetic concept formation was 7.8 (seven years, eight months) while the class mean for computational skills was 6.3. Each student then received 3.3 hours of the Suppes-Jerman math drill and practice CAI program. This was not supplemented by any other form of instruction. When the Stanford Achievement Test was administered after completion of the CAI programs, the computational mean was 7.4, a mean growth of one year, one month, and the concept mean was 9.8, a mean growth of two full years. A similar experiment conducted with a small group of Upward Bound enrollees yielded almost identical results. That these studies are both limited and crude is obvious; taken together with other evidence, however, they are suggestive of a potential measure of effectiveness of drill and practice CAI in remedial instruction, that is, in reaching students who have been derailed from the instructional track.

California Schools. The research team at the Institute for Mathematical Studies in the Social Sciences (Stanford) is in the process of

completing an extensive evaluation of their CAI program in drill and practice mathematics. Fragmentary results of these surveys have been made available and may be briefly summarized as follows. During the 1967-68 school year, experimental and control groups were established at seven different schools in grades one through six. The regular mathematics instruction of the experimental group students was supplemented throughout the entire school year with the Suppes-Jerman CAI drill and practice program while the control groups' instruction was not so supplemented. A battery of the Stanford Achievement tests in elementary level mathematics was administered to both groups, first in October, and then at the end of May. The results were: the students receiving CAI drill and practice had a statistically significant greater increase in performance level than the control students on the computation section of the SAT in grades 2, 3 and 5. Also, the CAI students achieved a significantly greater increase in performance level than the control students on the Concepts section for Grade 3 and on the Applications section for Grade 6. A very similar comparative survey has been conducted in McComb, Mississippi: the results of that survey provide an interesting comparison with the Stanford results.

McComb, Mississippi. The McComb evaluation is almost identical in design with the Stanford study. The Stanford Achievement tests were the standard of measurement: they were administered at the start of the experiment in the form of pre-tests and at the termination of the experiment as post-tests. Control groups and experimental groups were established in twelve different schools and included grades one through six. As in California, the regular mathematics instruction of the experimental students, over the entire school year, was supplemented by regular CAI drill and practice sessions while the control group students were not exposed to CAI. The results of the experiment are represented in Figure 4.

Figure 4: Statistical Results

Experimental vs Control Groups--Suppes (Stanford) Mathematics Drill and Practice

Location and Grades: McComb Public Schools, McComb, Mississippi, Grades 1-6
Dates: Pre-test September 1967 Post-test May, 1968
Test: Stanford Achievement

	Mean Pre-test Control	N^{ϕ}	Mean Pre-test Exp.	N^{ϕ}	Mean Post-test Control	Mean Post-test Exp.	Mean Post-Pre Control	Mean Post-Pre Exp.	t score post-pre	p	df
Computation											
Grade											
1	1.32*	63	1.41*	52	1.46*	2.55	.206*	1.135*	10.56	< .01	113
2	1.96	54	1.99	25	2.80	3.37	.84	1.42	5.23	< .01	77
3	2.76	56	2.82	22	4.04	4.85	1.26	2.03	4.64	< .01	76
4	2.45	77	2.26	58	3.17	3.36	.69	1.10	2.63	< .01	133
5	3.71	134	3.09	83	4.60	4.46	.90	1.37	3.43	< .01	215
6	4.36	160	4.82	275	5.48	6.54	1.13	1.72	5.18	< .01	433
Concepts											
Grade											
3	2.97	56	2.83	22	4.26	4.78	1.29	1.95	3.01	< .01	76
4	2.31	77	2.65	58	3.06	3.01	.74	.36	2.25		
5	4.00	134	3.42	83	5.24	4.78	1.29	1.37	.50		
6	4.88	160	5.34	275	5.39	6.31	.52	.98	3.74	< .01	433
Applications											
Grade											
4	2.88	77	2.89	58	3.28	3.33	.41	.44	.22		
5	4.12	134	3.56	83	4.73	4.33	.65	.77	.88		
6	4.52	160	5.06	275	5.06	6.13	.61	1.08	4.09	< .01	433

*grade equivalence in years and months
ϕ number of students

The impact of CAI, as Figure 4 shows, was considerably more pronounced in Mississippi than in California. The performance growth of the experimental students on the Computation section of the SAT was significantly better (at the .01 level of statistical significance) than the performance growth of the control students in all six grades. The most dramatic difference was at the first grade level where the average increase in grade placement for the experimental students was more than one year and one month while the average increase for the control students was less than two months.

The performance of the experimental students was significantly better (at the .01 level) than the control group students on the Concepts section for Grade 3 and Grade 6, and on the Applications section for Grade 6.

The Mississippi results, once again, are strongly suggestive of the potential of the drill and practice mode of CAI in upgrading the mathematical skills -- especially critical computational skills -- of low-achievers: in Figure 4 note the extent to which experimental group students were brought to or near their formal grade level after a year's exposure to CAI.

The responsible officials in McComb discern a number of educational

benefits as a result of the introduction of CAI. These improvements were, in most cases, very similar to those observed in Eastern Kentucky. There was, throughout the year, a high degree of student enthusiasm and motivation for the CAI program and, in many cases, toward the entire instructional process. There was no evidence of teacher fear of or skepticism toward CAI; rather, the teachers who were interviewed universally expressed, in very positive terms, gratitude for the benefits which they felt accrued both to the students and themselves as a result of CAI. As a result of the time made available and the diagnostic aid rendered by CAI, the teachers felt that they had more closely approximated the individualization of instruction than ever in the past. The attitude of the teachers toward the contributions of CAI were summarized by Mrs. Gayden Stovall, a sixth grade teacher, who said that she would prefer a CAI terminal in the classroom to the services of a teacher's aid and that she would accept a larger class, e.g., thirty-three rather than thirty students, if a terminal were available.

Some of the potential benefits of CAI have been indicated above. A final comment on this subject will be offered in the concluding remarks. Now, however, let us turn to the costs of CAI.

The Costs of CAI

The halting growth of CAI in elementary and secondary education has been, above all, a function of the high, indeed exorbitant costs of the medium. These costs include hardware, software, and general operating expenses. Until these costs are significantly reduced, it is impossible to predict when, if ever, CAI will be absorbed into the mainstream of the instructional process at the elementary and secondary levels. Contrary to my judgment, there are those who take the view that the impressive pedagogical benefits suggested by CAI research and demonstration projects will somehow result in the expenditure of the large sums necessary to widely disseminate state of the art CAI systems throughout the public school establishment. This is fallacious reasoning and its acceptance will retard the advent of operational, effective computer assisted instruction in the schools. First, one must consider the meager body of research on the learning effectiveness of CAI that exists -- and that is summarized within this report. On balance, this research indicates that, indeed, <u>when</u> CAI is more effective than traditional methods of instruction the learning gains are to be measured in arithmetical and not exponential terms; and, further, that CAI has proven more effective than traditional methods of instruction in the acquisition of a <u>limited</u> number of skills.

Past experience as well as ongoing research strongly suggests that the perfection of CAI as an instrument of learning will be a lengthy, difficult and tedious process: It is illusory to await a "Sputnik effect" to sustain the growth of this process.

Unfortunately, misconceptions about the financing of CAI do not end here. There is a rather widely held belief within the educational community -- by those who are involved in CAI research and development as well as those who are users or potential users of the medium -- that the advancing state of the art of computer technology will significantly reduce the costs of computers and peripheral equipment. This belief reflects a serious misunderstanding of the computer industry and its major marketing thrust. It is crucial to grasp this misunderstanding for it leads to an awareness of one of the major factors -- though not the only factor -- in the high cost of CAI.

Data processing equipment has, is, and will continue to be designed to serve the needs of extensive and well endowed commercial and scientific markets. The users in these markets require data processing equipment that possesses extremely sophisticated and complex capabilities. Existing CAI systems are created from this equipment which, in many cases, offers capabilities not needed, in other cases lacks required capabilities,

and is extremely expensive. The computers currently employed in state of the art CAI systems, for example, possess extremely large core memory capacity, extremely high computational speed, the ability to accommodate a wide variety of input-output devices, and frequently multiprogramming capability. The RCA Spectra 70/45 computer, the heart of the RCA IS 70 CAI system, for example, is a general purpose digital computer designed to handle data infinitely more voluminous and computations infinitely more complex than the dri... ...d practice algorithms which it processes in the New York City CAI project. Similarly, the computer which serves as the central processor for the IBM 1500 CAI system is a special purpose digital computer designed for process control. In truth, this computer fulfills its anticipated role in systematically ordering and monitoring the complex sequence of operations in an oil refinery and not in supplementing the teaching of economics to elementary school children as at Yorktown Heights, New York. In short, CAI systems are created with hardware designed for much different purposes and, to some extent, are priced on the basis of data processing capabilities and features which are irrelevant to computer assisted instruction.

Unfortunately for CAI, the general trend in the computer industry is toward even larger, more powerful, more sophisticated systems with enormous core memory capacities and increased computational speed.

This trend, for example, is at the heart of the recent lawsuit brought by Control Data Corporation against International Business Machines Corporation. CAI, in short, is caught in a vicious cycle. As long as the market for CAI systems remains small, industry cannot be expected to invest the necessary funds to develop a specially designed system which will be functionally relevant and significantly less costly. The CAI system market, however, will remain small as long as expensive hardware designed for commercial and scientific applications form the basis of CAI systems. The problem of the cost of CAI will not be eliminated either by "the invisible hand of the marketplace" or by the advancing state of the art of computer technology. Affirmative action is required to solve the problem. I shall return to this subject at the conclusion of this discussion of CAI.

Let us turn now to an examination of the precise hardware costs of CAI systems presently available in the marketplace.

IBM 1500 System

In terms of major components, this system consists of two computers which are provided with additional memory capacity by two disc storage units. The system provides sixty-four student instructional

terminals of a "rich" nature. That is, the terminals are equipped to provide the student with both audio and visual displays and allow the student to input information by means of both typewriter keyboard and light-pen. In this configuration, the sale price of the system is approximately \$1.2 million (maintenance charges included). The annual rental charge for this system is approximately \$380,000, including maintenance. These costs are itemized in Figure 5 below:

Figure 5: IBM 1500: Itemized Costs

Description & Model No.	Quantity	Monthly Rental	Price	Monthly Maintenance Charge
1131 - CPU 2B (Central Processing Unit)	2	$ 2,172	$ 29,170	$ 150
1132 - Printer	2	536	22,700	50
1442 - Card Reader/Punch	2	530	29,150	104
2310 - Disc Storage	2	700	27,000	53
1501 - Station Control	2	4,100	194,000	45
- Display Adapter	2	1,000	42,800	22
- Display Control	2	1,140	48,500	72
- Light-Pen Adapter	2	220	9,600	4
1505 - Audio Adapter	8	560	20,400	20
- Audio Tape Drive-Play/Record	64	6,400	255,360	1,344
1510 - Instructional Display	64	3,520	118,400	768
- Light-Pen	64	1,408	61,440	96
1512 - Image Projector	64	5,760	227,840	912
TOTAL		$ 28,046	$1,149,360	$ 3,640
ANNUAL TOTAL		$336,552		$43,680

Philco-Ford 102 System

There is a serious question as to whether this system is available in the open market. There is but one installation -- in the Philadelphia schools -- and there the system has been radically transformed in configuration. I include the cost figures on this system only in the interest of providing a broad view of state of the art CAI systems' costs. In terms of major components, this system is configured much like the IBM 1500: that is, two medium size computers, upgraded in memory capacity by two disc storage units, control 64 student terminals. These terminals, as in the IBM system, permit the student to receive visual materials which are displayed on a modified television receiver and to receive audio messages which are transmitted via headsets. The student may input information by means of a typewriter keyboard arrangement. In the configuration described above, the system was priced at $1.1 million. This total price is itemized below in Figure 6.

Figure 6: Philco-Ford 102 System

Device	Quantity	Price
CPU	2	$ 230,000
Magnetic Tapes	6	36,000
Printer	2	50,000
Card Reader/Punch	2	72,000
ASR (Teletype)	2	8,000
Input/Output Interface	2	72,000
Terminal Control Unit	2	290,000
Terminals	64	200,000
Disc Storage	2	140,000
TOTAL		$1,098,000
ANNUAL MAINTENANCE CHARGE		$ 24,000

RCA Instructional 70 System

This is the largest system which, at the present time, may be commercially procured. At the heart of the system is a large processor, the memory capacity of which is upgraded by a number of auxiliary storage units. The computer is linked to 192 instructional terminals. These terminals are modified teletypewriters: students receive information in the form of hard copy teletypewriter print-out and communicate with the computer by means of the teletypewriter keyboard. The annual rental fee for this system is $720,000. The rental costs are itemized below in Figure 7.

Figure 7: RCA Instructional 70 System

Description	Quantity	Total Monthly Rental
CPU (Spectra 70/45)	1	$11,125
Memory Protect	1	129
Elapsed-Time Clocks	1	52
Selector Channel	1	38[illegible]
Console	1	340
Card Reader	1	670
Magnetic-Tape Unit	3	1,860
Tape Controller	1	720
Random-Access Controller	2	1,080
Input-Output Attachment Feature	2	N/C
Disc Storage Unit	2	1,180
Disc Pack	10	150
Communication Controller M. C.	1	720
Synchronous Buffers	8	344
Record Overflow Feature	1	10
Card Punch	1	465
Printer	1	720
Line Concentrator	4	[illegible]0,360
Instructional Terminals	192	18,642
TOTAL		$59,652

Returning to the broader perspective of total CAI operating costs, let us focus upon the largest such system in existence and the pattern of expenditures which supports it. The New York City Board of Education Computer Assisted Instructional System consists of a total of one hundred ninety-two student terminals installed in sixteen elementary schools in The Bronx, Brooklyn and Manhattan. Six thousand students, Grades 2 through 6, receive individualized drill and practice on a daily basis.

The annual equipment rental totals $720,000 (see Figure 7 above). The annual communications costs, that is, the costs of the many telephone lines which link the remotely located instructional terminals to the central computer in Manhattan, are $144,000. The major software component, the mathematics drill and practice curriculum materials, are leased from the L. W. Singer Company at an annual cost of $19,200. The overall administrative costs associated with the project, including the costs of space rental, operating personnel, supplies, etc., are approximately $125,000 annually. The inclusive costs of CAI in the New York City schools, therefore, is just over $1 million a year.

In effect, New York City is incurring an annual per student cost of just over $183 for a CAI system which supplements instruction in one curriculum area at five of the thirteen formal learning levels. It is sobering to compare this figure with other educational expenses. For example,

the national median annual per student expenditure for textbooks in 1968 was $5.58. On a national average, in 1968, we spent $328.63 per student for classroom teachers, and only $20.98 for administration. These comparisons merely serve to provide added emphasis to the thesis expressed at the outset of this section: the costs of CAI must be radically reduced before there can be any reasonable expectation that the medium will be introduced into the mainstream of the instructional process at the elementary and secondary levels.

Several potential paths toward cost reduction deserve serious consideration. In the equipment or hardware area, one point of clarification is perhaps in order. Nothing that I have said should be interpreted as casting the manufacturers of data processing equipment into the role of the culprits responsible for high cost of CAI. This, for two reasons. These costs are the result of multiple causation, as I trust the analysis above makes abundantly clear. Second, it is unreasonable and unjust to expect industry to invest millions of dollars of risk capital in the design and development of an optimum CAI system for a market that has shown such limited potential. It is my judgment that a functionally relevant, moderately priced CAI system -- a cost-effective system -- would be created by an intensive collaborative effort of representatives of the computer industry,

engineers, learning theorists, and educators. Such an effort could become a reality were the federal government to supervise the design of specifications, organize a competitive bidding process, and subsidize the project. While this course of action raises serious questions of public policy, I am unable to envision alternative means of efficiently and expeditiously reducing CAI hardware costs.

Communications costs are a major factor in CAI expenses: in the New York City project, the leasing of telephone lines results in expenditures equivalent to twenty per cent of total equipment costs. The New York situation is symptomatic, for virtually all CAI projects will involve linking remote terminals to central computers. A subsidized tariff schedule similar to the GSA TELPAK program -- where the GSA leases and subleases interstate telephone lines at less than half the commercial rates -- would be a powerful stimulant to CAI cost reduction and growth. Several existing <u>interstate</u> CAI projects, e. g., the McComb-Stanford project, have benefited from participation in the GSA TELPAK program. These benefits, however, are not currently available to purely <u>intrastate</u> projects.

The problem of software costs is dealt with elsewhere; however, several factors bear brief consideration. The fact that, at the present time, only one major publisher offers but one CAI program for sale is not surprising in light of the extremely high program development costs and

the severely restricted existing market. Should, however, it become clear that the appearance of efficient and reasonably-priced hardware was imminent -- as a result of a federally subsidized program or any other means -- a number of major publishers would be prepared to invest significant capital in software development. This conclusion results from "off the record" interviews with responsible representatives of major publishers. Such a development, in turn, would result in the availability of a broad range of lower cost CAI programs. The crucial point is that (commercial) software availability and cost reduction follows hardware. In the past, there has been a belief that CAI software could and should be developed locally by the educational user, e. g., a school district. Abortive attempts in this direction at several installations are a matter of record. The inability of schools to attract and pay the curriculum design, systems analysis, and programming personnel needed to do the job make it clear that software must be developed either in the publishing industry or in regional centers which pool broadly invested material and intellectual resources.

A Note on Software

In effect, the outlines of the CAI software situation, by implication, have been sketched in other sections of this report. Precious few CAI

programs, suitable for use in operational elementary/secondary installations, are available from any source. As mentioned above, only one CAI program, math drill and practice is available from a commercial publisher. While some two hundred thirty CAI programs have been developed over the past decade, the overwhelming majority of these were created in academic research centers and bear little relevance to the elementary and secondary curricula. Presently, there are several research centers concentrating on the development of CAI programs for the public schools. The most prominent of these centers are located at Stanford University under the leadership of Professor Patrick Suppes, at Florida State University under the leadership of Professor Duncan Hansen, and at the Pennsylvania State University under the leadership of Professor Harold Mitzel. In light of the limited financial resources available to these centers, however, it is unrealistic to assume that their efforts will result in the availability of a significant number of CAI programs in the near future.

The development of CAI materials in the publishing industry can be briefly summarized. The L. W. Singer Company, which offers the Computer-Based Drill and Practice in Arithmetic program, has no additional programs under development. Harcourt, Brace & World, Inc. has developed

an elementary level English drill and practice program (Grades 4, 5 and 6) and a drill and practice program in Remedial Reading at the junior/senior high school levels. These programs, however, will be validated in the field and not available for sale for at least one year. Harcourt, at the present time, plans no new course development. No other publishers involved in CAI development were identified. As emphasized previously, however, this situation would quickly change with the appearance of moderately-priced CAI hardware systems. One caveat, however, should be made. Publishers are extremely concerned about the lack of adequate copyright protection for CAI program materials. Under existing copyright regulations, there is a widespread fear that these materials would be reproduced without compensation to the publisher of origin. In summary, the key to software availability lies in the development of lower cost hardware <u>and</u> copyright protection of CAI materials.

A Concluding Note

Intensive, systematic, interdisciplinary studies of the effectiveness of operational CAI projects are urgently required. If such studies validate the findings of the fragmented and limited studies which have been conducted, state of the art CAI systems might well make a dramatic impact upon remedial education at various levels: in the schools of our economically

depressed urban and rural areas as well as in the skill and job training of the disadvantaged.

While this report has consistently qualified the limited evidence supporting the pedagogical potential of CAI, there is little doubt in the mind of the author --- based on extensive experience with the application of educational technology --- that the medium possesses tremendous potential for supporting the individualization of instruction. If this potential is to be realized within a reasonable time, a CAI system must be developed which possesses the data processing capabilities peculiarly required by the CAI process and the system must fall in a much lower price range than state of the art systems. Federal and state educational funding authorities must supply the initiative for this program of research and development.